IRC Senses Your Current

.005Ω ± .00005Ω

IRC
THE RESISTOR PEOPLE
A TT Group Company

Commercial/Military Advanced Film, Metal Glaze and Wirewound Resistors

P.O. Box 1860 • Boone, NC 28607 • 704-264-8861 • FAX: 704-264-8865

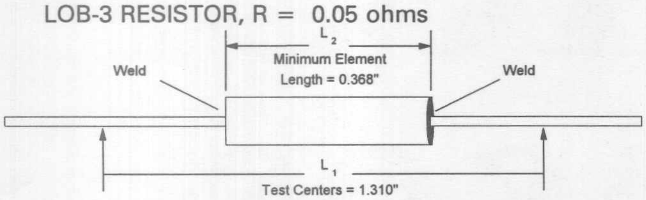
June 1994

Temperature Coefficient of Resistance For Low-Ohm Resistors

The temperature coefficient of resistance (TCR) is directly proportional to that part of the total resistance which is contributed by the copper leads. To calculate the temperature coefficient of a resistor the length of the leads must be determined from the weld. (The leads on stable low value resistors are attached by welding or by silver solder)

example:

LOB-3 RESISTOR, R = 0.05 ohms



(should be same as distance between connections to PC board)

Copper Resistivity ρ	
Lead Diameter	**ρ**
0.032"	0.000889 Ω/inch
0.036"	0.000679 Ω/inch
0.040"	0.000549 Ω/inch

$$\text{TCR of Resistor} = \left(\text{TCR contribution of copper leads}\right) + \left(\text{TCR contribution of resistive element}\right)$$

TCR Contribution Of Copper Leads

$$= \left(\text{Resistance of copper as fraction of total resistance}\right) \times \text{TCR copper}$$

$$= \left(\frac{L_1 - L_2 \times \rho \text{ copper}}{\text{Total Resistance}}\right) \times 3930 \text{ ppm/°C}$$

$$= \left(\frac{1.310" - 0.368" \times 0.00089\Omega/\text{inch}}{0.05\Omega}\right) \times 3930$$

$$= \left(\frac{0.942" \times 0.00089}{0.05}\right) \times 3930$$

$$= \frac{0.000838}{0.05} \times 3930$$

$$= 0.01676 \times 3930$$

$$= 65.87 \text{ ppm/°C}$$

TCR Contribution of Resistive Element

$$= (1.000 - \text{copper fraction from above}) \times 20\text{ppm/°C element}$$

$$= (1.000 - 0.01676) \times 20$$

$$= 0.98324 \times 20$$

$$= 19.66 \text{ ppm/°C}$$

TCR of Resistor

$$= 65.87 + 19.66 = 85.53^{*} \text{ppm/°C}$$

* This calculation provided the worst-case TCR for this resistor since the minimum element length was used.

Calculation Of TCR For Resistor Types LOB, PLO, & LPW

Use same method of calculation shown at left, by using the minimum element lengths shown below.

Resistor	Min. Element Length	Resistor	Min. Element Length
LOB-1	0.240 inch	PL0-15	1.452 inch
LOB-3	0.368 inch	LPW-3	0.432 inch
LOB-5	0.598 inch	LPW-5	0.432 inch
PLO-3	0.523 inch	LPW-7	0.918 inch
PLO-5	0.523 inch	LPW-10	1.320 inch
PLO-7	0.987 inch	LPW-15	1.320 inch
PLO-10	1.452 inch		

Calculation Of TCR For Types PWRL, OAR, & PLO-2

These types have relatively fixed lead lengths, therefore the element length is the main variable.

example:

OAR-1, R = 0.05 ohm, copper leads
0.125" max length, 0.040" diam.

TCR Contribution Of Copper Leads

$$= \frac{\text{Lead Length} \times 2 \times \Omega/\text{inch}}{\text{Total Resistance}} \times 3930 \text{ ppm/°C}$$

$$= \frac{0.125" \times 2 \times 0.000549}{0.05} \times 3930$$

$$= \frac{0.000137}{0.05} \times 3930$$

$$= 0.00274 \times 3930 = 10.77 \text{ ppm/°C}$$

TCR Contribution of Element

$$= (1.000 - 0.00274) \times 20 = 19.95 \text{ ppm/°C}$$

TCR of Resistor

$$= 10.77 + 19.95 = 30.72 \text{ ppm/°C}$$

example:

OAR-1, R = 0.02 ohm

TCR Contribution Of Copper Leads

$$= \frac{0.125" \times 0.000549}{0.02} \times 3930$$

$$= 0.00686 \times 3930 = 26.96 \text{ ppm/°C}$$

TCR Contribution Of Element

$$= (1.000 - 0.00686) \times 20$$

$$= 0.99314 \times 20 = 19.86 \text{ ppm/°C}$$

TCR Of Resistor

$$= 26.96 + 19.86 = 46.82 \text{ ppm/°C}$$

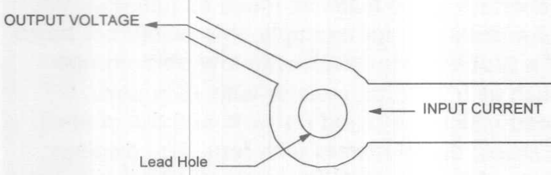
Lead Length Factors			
Resistor Type	**Factor (lead length x 2)**	**Resistor Type**	**Factor (lead length x 2)**
OAR-1	0.25 inch	PWRL-3	0.50 inch
OAR-3	0.30 inch	PWRL-5	0.50 inch
OAR-5	0.30 inch	PWRL-7	0.50 inch
PLO-2	0.25 inch	PWRL-10	0.50 inch

Two-Leaded Versus Four Leaded Resistors

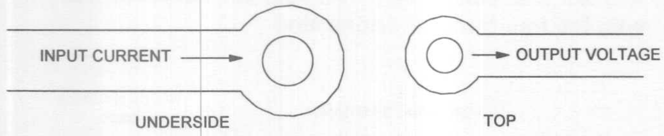
- Four-leaded resistors are much more complex to manufacture than those with only two leads, and are therefore more costly, typically 2 to 4 times that of two-leaded devices.
- Four-leaded resistors are much more difficult to install on a PC board.
- Four-leaded resistors should be used only when a TCR of 30 ppm or less is required.

How to Achieve Four Terminal Hookup On PC Boards Using Two-Leaded Resistors

I. For use of a PC board with the electrical traces on only one side of the board.



II. For use of a PC board with electrical traces on the top and underside connected with a plated thru hole.



IMPORTANT NOTICE:

1. Make sure the input trace is large enough to carry the input load current.
2. With a two-sided board, test resistance on the top side directly on the resistor terminals.

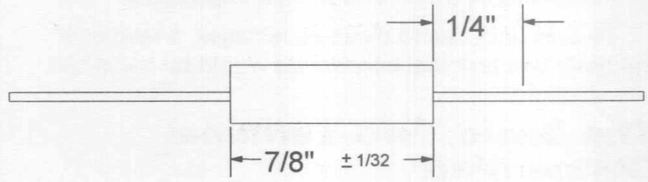
How To Specify Two-Leaded Low Ohm Resistors

(less than 0.1Ω)

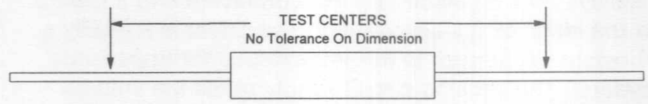
MOUNTING CENTERS OR TEST CENTERS

The resistor should be mounted using a lead length as short as possible in order to minimize the TCR.

A. Test centers - incorrect method
Test points should not be specified as a distance from the end of the resistor since this allows the tolerance of the body length to affect the test results.



B. Test centers should be identified as shown below.



When requested, IRC will include a resistor in a sample order which has the resistance recorded at a specified test center. With use of a digital ohmmeter this can then be used as a calibration standard in order to adjust the test centers to exactly duplicate the known resistance value provided with the resistor. This method of establishing test conditions has been found to be much faster and more accurate than methods which use physical dimensions as the basis for the test.

More Accurate and Improved Measurements Using Four Terminal Connections

The method by which leads are attached to a component can affect measurement results significantly. Of the many methods, the four terminal connection is the most widely used for precision measurements. This is especially true in low resistance (R), low inductance (L), and high capacitance (C), measurements. Some advantages include:

- Reduces the effects of terminal resistance.
- Reduces the effects of contact resistance.
- Minimizes the effects of lead impedance.

To best understand these advantages, a review of the basic two-terminal connection would be beneficial.

The Basic Two-Terminal Connection

The measurement procedure is straight forward. This is generally accomplished with the use of a meter. The meter is comprised of two essential circuits; the driver circuit, labeled "D" in fig. 1, and the sensing circuit, or measurement circuit, labeled "S". Figure 1 displays how these circuits are connected and attached to the leads of the component. The driver is typically a constant DC current in ohmmeters (AC for impedance meters). The sensing circuit simply reads the voltage drop across the component caused by the driver. The drive current is prevented from flowing through the sensing circuit due to the high impedance it presents.

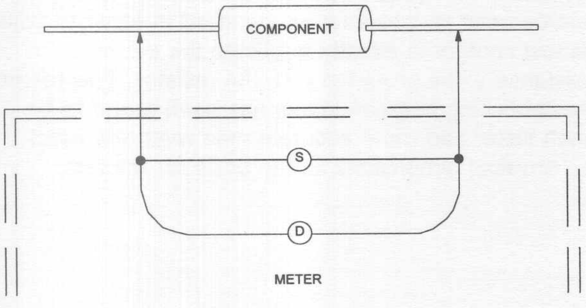


Figure 1
A simplified two-terminal meter consists of typically two circuits; the measurement or sense circuit (S) and the drive circuit (D).

The first step in measuring with a meter is zeroing. This is accomplished by shorting the two test leads together until zero is registered on the display. This essentially drops the voltage to zero across the test leads. Some modern meters automatically perform this process with the auto-zeroing feature.

The next step is to physically connect the test leads to either side of the component, as shown in Fig. 1. With this process, the driver circuit within the meter sends its known current across the component. The measuring circuit then processes this known current into a voltage which is displayed on the meter.

The Two-Terminal Disadvantage

One problem with two-terminal measurements is that the meter does not only record the voltage across the component itself, but also adds in the voltage at the terminals of the circuit within the meter, labeled A & B in figure 2. The voltage at these two points is the total added sum of the voltage dropped across the meter leads, plus the voltage drop in the terminal leads of the component, plus the voltage drop of the component itself. Therefore, the only true reading of the component would have to be processed with the contact and lead voltages not present. This is not possible with a two-terminal connection.

The added extra voltage can be reduced, however, by zeroing the meter, as mentioned previously, and also by shortening the leads as much as possible. With higher ohm resistors, for example, this would not be so much of a problem. However, with low ohm components, such as a 0.5 ohm resistor with ±5% error, 0.1 ohm added resistance could throw it well out of spec. In these cases, digital meters with four digit displays may not be of much use. When zeroed, the meter may display 0.000, but may very well be reading 0.000438. This resistance is still present even though it is not displayed. Even if there is an accurate zero reading, the resistance of the leads attached to the component would not be compensated. This poses a problem for a two terminal connection. The solution, however, lies with the four terminal connection.

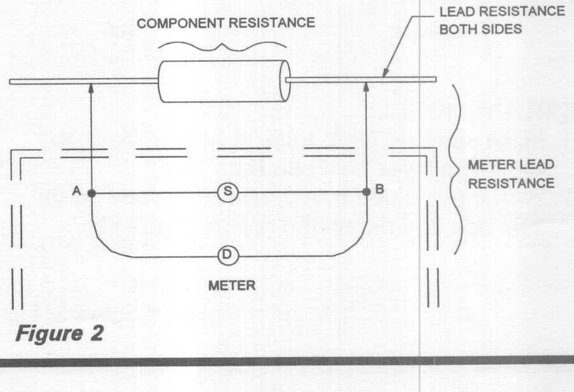


Figure 2

The Four-Terminal Solution

Resistance of the leads within the meter that causes two-terminal measurement error is present due to the drive current. This drive current is supplied by the same leads used to sense voltage across the component. Four terminal connection solves the problem of internal lead resistance.

Figure 3 shows the path of current driven through the component by way of the upper drive (UD) and lower drive (LD) leads. The drive current still causes a voltage drop across the UD and LD leads as well as the actual component. However, the sensing current only reads voltage across the component due to the separate set of sense leads (labeled US and LS).

Since the sensing circuit has such a high impedance, it draws very little current. Without lead current, there can be no lead voltage drop which would add to the total measured value of the component. This eliminates the lead resistance error from the measurement.

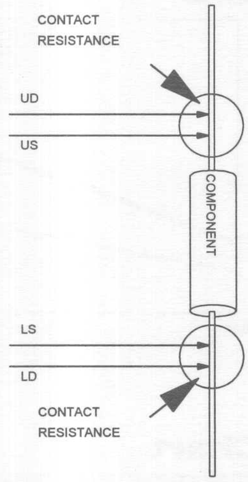
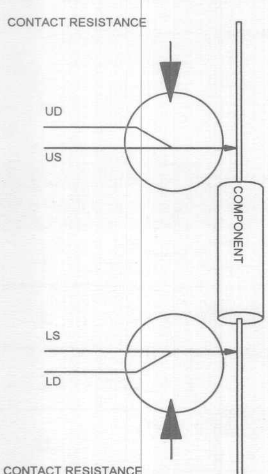


Figure 3 →

This displays the proper method of connecting the four leads to the terminals of the component. These separate contact leads eliminate contact resistance error from the measurement circuit.



← Figure 4

This displays the incorrect method of merging the four leads together in order to measure the component. This method will result in error due to the contact resistance.

The Elimination Of Contact Resistance

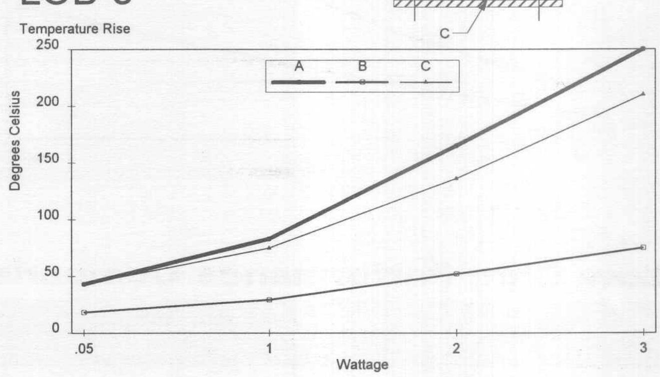
The four lead termination will eventually work it's way back to a two terminal connection. Since there are only two terminals on a component, all four leads must be connected to the two terminals at some point before measurement.

Contact resistance can only be eliminated if the four leads are merged into two properly, as in figure 3. Figure 4 displays the improper method of merging the leads together. Here the leads are joined before they contact the components terminals. With this method, the sensing leads read any voltage drop caused by the driver circuit through the contact resistance. Thus, the resistive value is added to the total measurement defeating the purpose of the four terminal leads.

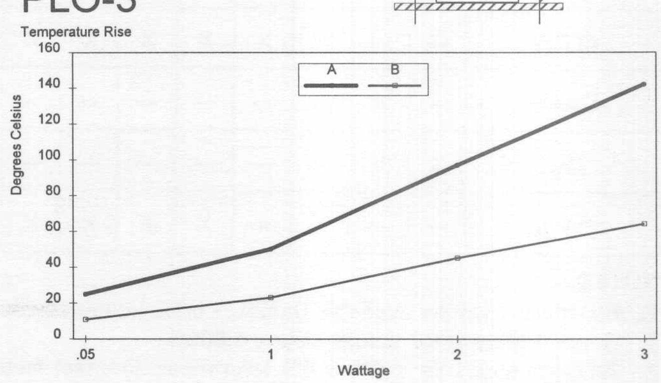
Figure 3 shows the correct method of connecting the four leads to the terminals of the component. The voltage drop across the drive circuit is not seen due to the four separate contacts. The sensing leads are not able to read the voltage drop across the driver circuit due to the separate inner connections of the component. In addition, since there is almost no current through the sense leads, the resistance of it's contact present no voltage drop. Thus, the four terminal method eliminates the source of error from the measurement circuit.

Temperature Rise

LOB-3

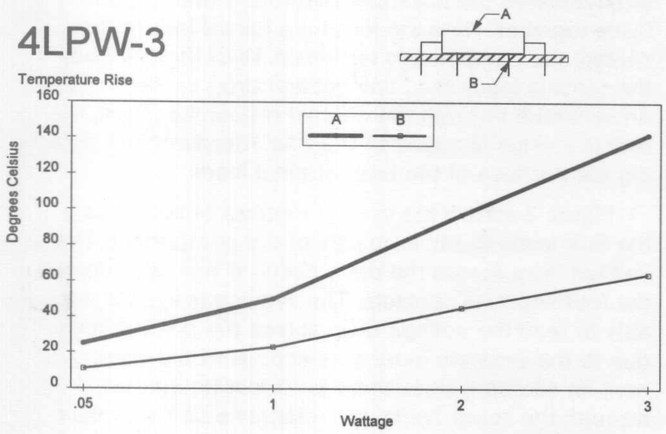


PLO-3

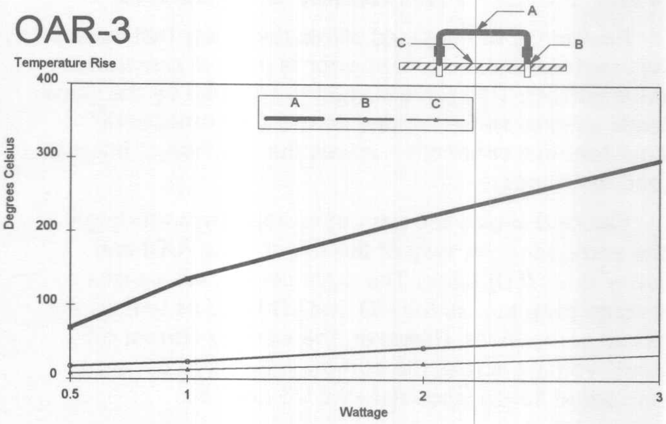


IRC

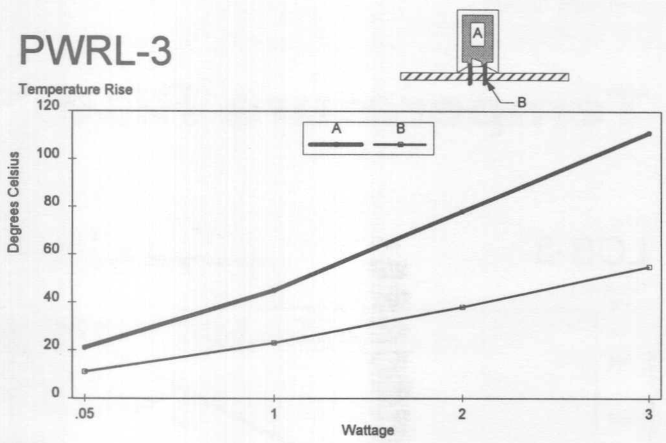
4LPW-3



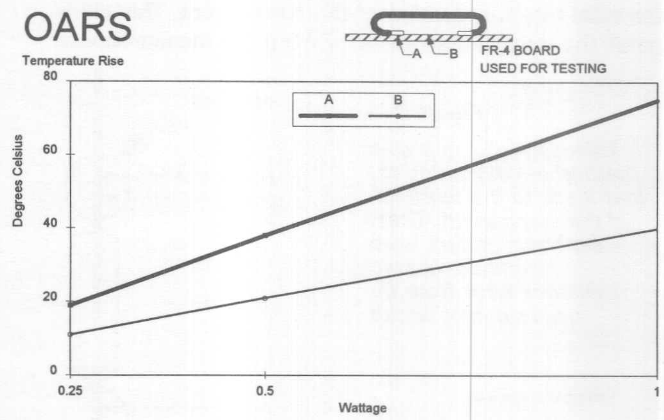
OAR-3



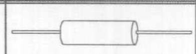
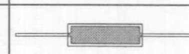
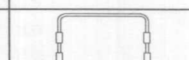
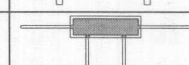
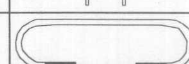
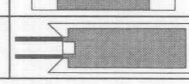
PWRL-3



OARS



Low Ohm Performance Comparison Chart

Product	Available Power Rating 1/2	1	2	3	5	7	10	15	Temp. Coef. (1-Best, 7-Worst)	Placement Method	Physical Configuration	Price Indicator (1-Low, 6-High)
LOB	—	X	—	X	X	—	—	—	6	Auto Insert		1
PLO	—	X	X	X	X	X	X	X	4	Hand Insert		4
OAR	—	X	—	X	X	—	—	—	3	Hand Insert		1
4LPW	—	—	—	X	X	X	X	X	1	Difficult Hand Insert		6
OARS	—	X	—	—	—	—	—	—	2	Surface Mount		2
LRC	X	X	—	—	—	—	—	—	7	Surface Mount		3
PWRL	—	—	X	X	X	X	X	X	5	Hand Insert		5

NOTES:
1. Resistance values available 0.005Ω - 0.1Ω (exception is LRC with min. 0.025Ω)
2. Contact factory for values below 0.005Ω
3. All parts available in 2% & 5% tolerances. (contact factory for tighter tolerance and matching)
4. Price ranges in normal production values are $0.25 - $1.50

IRC
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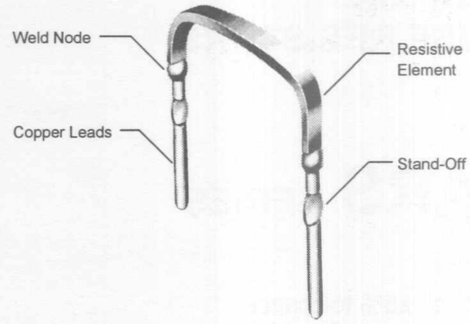
OPEN AIR SENSE RESISTORS

OAR SERIES

- 1, 3 & 5 watts
- ±1% or ±5% tolerance
- resistance wire TCR ±20 ppm/°C



SPECIFICATIONS:

IRC Type	IRC Power Rating* (watts)	Available Resistance** (ohms)
OAR-1	1W @ 25°C	0.005 ohms to 0.10 ohms
OAR-3	3W @ 25°C	0.005 ohms to 0.10 ohms
OAR-5	5W @ 25°C	0.005 ohms to 0.025 ohms

FEATURES:

- Welded construction
- Flameproof
- Inductance less than 10 nanohenries
- Solderable copper leads (60/40 plated)

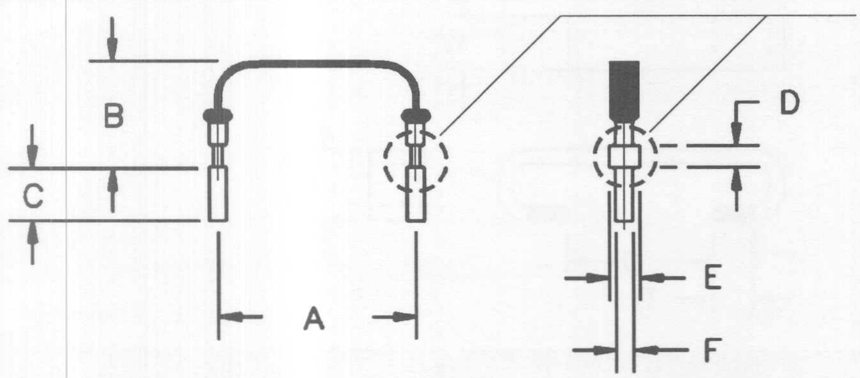
APPLICATIONS:

- Current sensing
- Feedback
- Low inductance
- Surge and pulse

OPERATING CHARACTERISTICS:

- Load life @ 25°C (1000 hrs): 1% max.
- Moisture no load (1000 hrs): 1% max.
- Temperature cycle @ -40°C & +125°C (1000 cyc): 1% max.

DIMENSIONS (Inches and (mm)):



on lower ranges stand-off may be eliminated

NOTE:
Contact Factory For:
1. Variations of "A" Dim.
2. Different lead dia.
3. For resistance values below 0.005 ohms

IRC Type	A	B	C	D	E	F
OAR-1	$0.450^{+0.040}_{-0.020}$ ($11.43^{+1.020}_{-0.508}$)	$0.200^{\pm0.100}$ ($5.08^{\pm2.54}$)	$0.125^{\pm0.030}$ ($3.18^{\pm0.762}$)	$0.050^{\pm0.005}$ ($1.27^{\pm0.127}$)	$0.065^{+0.010}_{-0.005}$ ($1.65^{+0.254}_{-0.127}$)	$0.040^{\pm0.002}$ ($1.02^{\pm0.051}$)
OAR-3	$0.600^{+0.040}_{-0.020}$ ($11.43^{+1.020}_{-0.508}$)	$1.0^{max.}$ ($25.4^{max.}$)	$0.125^{\pm0.030}$ ($3.18^{\pm0.762}$)	$0.050^{\pm0.005}$ ($1.27^{\pm0.127}$)	$0.065^{+0.010}_{-0.005}$ ($1.65^{+0.254}_{-0.127}$)	$0.040^{\pm0.002}$ ($1.02^{\pm0.051}$)
OAR-5	$0.800^{+0.040}_{-0.020}$ ($11.43^{+1.020}_{-0.508}$)	$1.0^{max.}$ ($25.4^{max.}$)	$0.125^{\pm0.030}$ ($3.18^{\pm0.762}$)	$0.050^{\pm0.005}$ ($1.27^{\pm0.127}$)	$0.065^{+0.010}_{-0.005}$ ($1.65^{+0.254}_{-0.127}$)	$0.040^{\pm0.002}$ ($1.02^{\pm0.051}$)

WIRE AND FILM TECHNOLOGIES
PO Box 1860 • Boone, North Carolina 28607-1860 • Tel: 704-264-8861 • Fax: 704-264-8865

IRC
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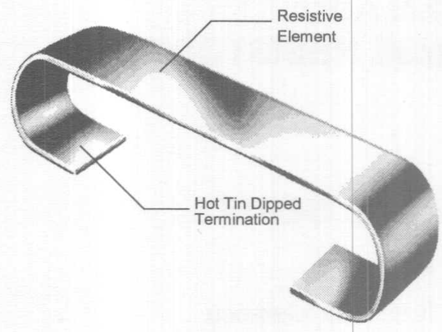
PRELIMINARY

OPEN AIR SENSE RESISTORS



OARS SERIES

- 1 watt
- ±1% or ±5% tolerance
- resistance wire TCR ±20 ppm/°C

SPECIFICATIONS:

IRC Type	IRC Power Rating (watts)	Available Resistance* (ohms)
OARS-1	1W @ 70°C	0.005 ohms to 0.10 ohms

* Contact factory for values from 0.05 to 0.1 ohms

FEATURES:

- Superior thermal expansion cycling
- Inductance less than 10 nanohenries
- Flameproof
- Solderable pads (60/40 plated)

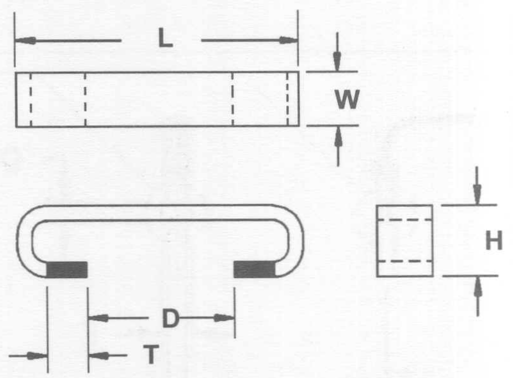
APPLICATIONS:

- Current sensing
- Feedback
- Low inductance
- Surge and pulse

OPERATING CHARACTERISTICS:

- Load life @ 70°C (1000 hrs): 1% ΔR max.
- Moisture no load (1000 hrs): 1% ΔR max.
- Temperature cycle @ -40°C & +125°C (1000 cyc): 1% max.

DIMENSIONS (Inches and (mm)):



IRC Type	L	H	T	D	W
OARS-1	$0.440^{\pm0.015}$ ($11.18^{\pm0.381}$)	$0.120^{\pm0.030}$ ($3.05^{\pm0.762}$)	$0.093^{\pm0.010}$ ($2.36^{\pm0.254}$)	$0.190^{\pm0.030}$ ($4.83^{\pm0.762}$)	0.125max. ($3.175^{max.}$)

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